The Pharma Innovation Journal 2021; 10(7): 633-639

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(7): 633-639

www.thepharmajournal.com
Received: 08-04-2021
Accepted: 29-06-2021

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A mini review on osmotic dehydration of fruits and vegetables

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Abstract
Fruits and vegetables are an essential source of nutrients in the human diet. Fresh fruits and vegetables contain 75-95 percent water, and osmotic dehydration is one way to reduce the water content initially. Osmotic drying is a partial dehydration process that, in comparison to traditional drying, improves the product's consistency. The osmotic treatment entails soaking a food in a hypertonic sugar and/or salt solution for a set amount of time at a given temperature. When compared to other drying processes, the process has two major advantages. As compared to products from traditional drying methods, the consistency of osmotically dehydrated products is higher and shrinkage is significantly lower. Second, in comparison to other drying methods, the technique helps to save total resources. Because of the high latent heat of vaporization, moisture removal through phase change (evaporation of water) is an energy-intensive process. There is no phase change during osmotic dehydration, so the process can be completed with minimal energy input, which is the primary explanation for the energy savings. To reduce the amount of energy & maximize the profit used in food drying, new technologies are constantly being tested. Several countries are conducting research into osmotic dehydration's applications in food processing technology and component transition mechanisms. Traditional food dewatering methods include osmotic dehydration. It produces appealing, ready-to-eat items or can be used as a pretreatment for subsequent processes like drying or freezing. It's a process that uses less resources.

Keywords: Osmotic dehydration, moisture, traditional drying, freezing, fruits and vegetables

Introduction

Natural foods, such as fruits and vegetables, are among humanity's most valuable foods because they are not only nutritive but also essential for health maintenance. India is the world's second-largest producer of fruits and vegetables (Shete, Y.Y *et al.*, 2018) [32]. The cultivation of vegetables and fruits accounts for more than 30% of the agricultural GDP. However, the real challenge begins after the production is completed (Yadav, A.K & Singh, S.V., 2014). Because of its high perishability, its storability after harvesting is reduced (Kumar & Nath, 1993). In India, nearly 30% of the crop was lost due to poor post-harvest practices, which resulted in the fruit spoiling or being damaged during transportation. To avoid problems and protect the fruit's development and life, proper post-harvest treatment must be followed step by step. Otherwise, supply would not be able to keep up with demand, resulting in a price increase. As a result, investors could be dissatisfied. As a result, proper low-end processing techniques are needed to protect grower interests and keep prices within natural ranges. The high-water content of fruits and vegetables is the key cause of their perishability (Yadav, A.K & Singh, S.V., 2014). Fruit weakens as a result of physiological and biochemical changes, which cause an increase in respiration and ethylene production, resulting in discoloration, loss of firmness, creation of off flavors, acidification, and microbial spoilage. To solve these issues, researchers must develop low-cost, high-yield processing techniques. Many methods or combinations of methods have been tried to extend the shelf life of these fruits and vegetables.

Water is a major component of foods, and it has an effect on both microbial and chemical food stability. It influences consumer perceptions of juiciness, elasticity, tenderness, and texture, among other organoleptic qualities (Phisut, N., 2012) [13]. The key challenge in preserving food (Lenart, 1996) [29] is to remove water and reduce the moisture content to a degree that enables safe storage for a prolonged period of time. The removal of water from fruits and vegetables by drying is one of the oldest and most significant methods of food preservation known to man. Water, as one of the most important food ingredients, has a direct impact on the quality and longevity of foods by influencing a variety of physiochemical and biological changes (Fabiano A.N.F *et al.*, 2006).

The aim of this ancient preservation technique is to allow for longer periods of storage with reduced packaging, lower shipping weights, and preserve dehydrated plant products so that they are accessible to customers throughout the year (Wakchaure *et al*., 2010) [20].

The food industry's main concern is preserving food to prolong its shelf life while maintaining its protection and quality. As a result, a steady stream of new minimal preservation methods has emerged. Simultaneously, the advancement of the hurdle concept has rekindled interest in the use of more conventional preservation approaches, as well as the ways in which they can be integrated with newer technologies (Yadav, A.K & Singh, S.V., 2014). Traditional air drying is a high-cost method that involves simultaneous heat and mass transfer as well as phase change (Barbanti *et al.*, 1994) [27]. There have been a number of studies that have looked into the issues with traditional convective drying. Long drying times, disruption to sensory and nutritional properties of foods, and solute migration from the food's interior to the surface, resulting in case hardening are the key drawbacks of convective drying (Sharma & Prasad, 2005) [57]. Different pre-treatments and new low temperature & low energy drying methods are evolved to reduce the operational cost (Bal *et al.*, 2010) [26]. Dehydration is an essential process in the food industry for preserving raw food materials and goods. Controlled atmosphere storage, modified atmosphere storage, and dehydration are only a few examples of these techniques. Dehydration is a practical and cost-effective solution. Dehydration has a number of benefits over other methods, including reduced weight, low-cost packaging, dry shelf stability, and minimal quality degradation due to enzymatic changes (Alam, M.S. *et al*., 2010) [31].

Omotic Dehydration

Because of the minimal processing, the production of intermediate moisture food by the use of osmotic dehydration has gained a lot of attention from consumers in recent years (Ahmed *et al.*, 2016) [15]. To minimize overall processing and air-drying time, a pretreatment such as osmotic dehydration may be used (Fabiano, A.N.F *et al.*, 2006). Osmotic dehydration is a dynamic mass transfer mechanism that is complicated. Owing to the high osmotic pressure and low water activity of the osmotic solution, water in the cells of the materials permeates into the osmotic solution via the cell membrane. The water content of vegetables and fruits can be reduced by half (50%) using this osmotic dehydration method. Osmotic dehydration is often used as a pretreatment for drying biological materials because it is less expensive than thermal drying (Pan, Y.K *et al.*, 2000) [33]. It entails dehydrating fruit slices in two stages: removing water using an osmotic agent (osmotic concentration) and then dehydrating the product further in a dryer to minimize moisture content and make it shelf stable (Ponting, 1973) [41]. Sucrose, glucose, sodium chloride (vegetables), calcium chloride, lactose, fructose & starch concentrates (Ahmed *et al.*, 2016) [15] malto dextrin, corn syrup, and mixtures of these products were the most widely used osmotic agents (Sonia, N. S *et al*., 2015) [60]. Sucrose solutions with concentrations ranging from 50 to 70 Brix have been used to dehydrate fruits (Lerici *et al.*, 1985) [5]. The osmotic method has gotten a lot of attention as a pre-treatment for saving energy and improving food quality (Jayaraman & Das Gupta, 1992) [58]. In addition to reducing drying time, osmotic dehydration as a pre-treatment inhibits enzymatic development, preserves natural colour (without the addition of sulphites), and preserves volatile aromas during subsequent drying (Pokharkar *et al.*,1997) [28]. The benefit of OD is that it uses less energy and causes less product thermal harm because the lower temperatures used allow nutrients to be retained (Shi *et al.*, 1997) [43]. The key benefits of using OD, according to Lenart (1996) [29], are a lower process temperature, a sweeter dehydrated product, a 20–30% reduction in energy consumption, and a shorter drying period. The osmosis method separated water from fruit slices to the extent of 40–50% of the weight, but not enough for storage, according to the osmosis air-dried items, which were of superior quality.

As a result, additional drying is needed to get the water level down to safe levels (Vipul Chaudary *et al.*, 2018). To achieve a higher-quality finished product, osmotic dehydration is normally accompanied by other drying methods such as air drying, deep fat drying, freeze drying, and so on (Khan, 2012) [23]. According to Bongirwar and Sreenivasan (1977) [37], high temperatures above 600C alter tissue characteristics, favouring impregnation and thus solid benefit. The rate of sucrose diffusion is a function of solute concentration and temperature, according to Rahman and Lamb (1990) [18]. During osmosis, the diffusion coefficient decreased as the solid material increased and increased as the drying air temperature increased. Various fruits and vegetables, such as apple, banana, carrot, cherry, citrus fruits, guava, mango, and others, have been studied for osmotic dehydration by several researchers (Torreggiani and Bertolo, 2001) [63].

O.D principle

OD is a technique for producing clean, durable, nutritious, delicious, cost-effective, and concentrated food by immersing solid foods, whole or sliced, in sugar or salt aqueous solutions with high osmotic pressure (Sethi *et al.*, 1999) [55]. Water diffuses from a dilute solution (Hypotonic solution) to a concentrated solution (Hypertonic solution) across a semipermeable membrane before equilibrium is reached. The concentration gradient between the solution and intracellular fluid acts as a driving force for water removal. Solutes cannot diffuse through the membrane into the cells if the membrane is perfectly semi-permeable. Due to the complex internal structure of food systems, it is difficult to achieve a complete semi-permeable membrane, and there is often some solid diffusion into the food, implying that OD is a mixture of water and solute diffusion processes (Chandra, S. & Kumari, D., 2015) [34].

Osmotic dehydration's mechanism

Osmotic dehydration is achieved by immersing foods like fruits and vegetables in concentrated soluble solid solutions with a lower water activity and higher osmotic pressure. Dehydration is caused by a difference in the chemical potential of water between the food and the osmotic medium (Shete, Y.V *et al.*, 2018) [32]. It's simple to do at room temperature, which ensures colour, texture, and nutrients are preserved with minimal volatile compound loss and oxidative changes (Hasanuzzaman *et al.*, 2014) [18] Osmosis is the passage of water molecules down a water potential gradient through a selectively permeable membrane. Water movement through a selectively permeable membrane from a region of high-water potential (low solute concentration) to a region of low water potential (high solute concentration) (Rastogi *et al.*, 2002) [9]. Osmotic treatment is a procedure that combines dehydration and impregnation to reduce the harmful effects of fresh food components. It is the process of partially removing water from a substance by contacting it directly with a hypertonic medium, such as a high concentration of sugar or salt solution for fruit and vegetables. The concentration gradient between the solution and the intracellular fluid is the driving force for water removal after immersing a water-rich fresh food substance in a hypertonic solution. The solute is unable to pass through the membrane into the cells if it is perfectly semipermeable. Due to the complex internal structure of food materials and the possibility of damage during processing, it is difficult to achieve a complete semipermeable membrane. Two big countercurrent flows are present at the same time during osmotic processing. The first is water movement into the osmotic solution from the inside of the samples, and the second is osmotic agent diffusion in the opposite direction, from solution to product. Another minor flow is that of vitamins, organic acids, saccharides, and mineral salts, which flow from food into the osmotic solution. Despite the fact that this third flow contributes so little to the mass exchange, it can have an effect on the final nutritional values and organoleptic properties of food (Lazarides, 2001 [7]; Khin *et al.,* 2005) [6]. With the passing of time, the phase of mass transfer and tissue shrinkage spreads from the surface to the centre of the material. After a prolonged duration of liquid-solid interaction, the cells in the material's centre lose water, and the mass transfer flux is likely to equilibrate. During osmotic dehydration process, tissue shrinkage and mass transfer occur at the same time (Ahmed *et al*., 2016) [15]. As a result, mass transfer and tissue shrinkage are related to a particular part of the entire material for a given operating period (Le Maguer *et al.,* 2003 [8]; Shi and Xue, 2009) [10]. Water is transported through many processes simultaneously after food content is immersed in the osmotic solution: molecular diffusion, liquid diffusion, vapor diffusion (through gas flow), hydrodynamic flow, capillary transport, surface diffusion, and most often a mixture of these mechanisms.

Osmotic Process Influencing Parameters

Method parameter selection is often influenced by the programme. Choosing the best process parameters prevents undesirable changes from occurring in certain raw materials, especially those with a delicate structure (Ciurzynska *et al.*, 2016) [17]. For many fruits, such as papaya, the impact of key process variables (concentration and composition of the osmotic solution, temperature, immersion time, pre-treatment, agitation, nature of the food and its geometry, and ratio of solution to sample, among others) on the mass transfer mechanism and product quality has been extensively studied, papaya is a tropical fruit that is native to Southeast (Jain *et al.*, 2011) [62] banana (Verma *et al.*, 2014) [24] Mango (Oladejo *et al.*, 2013) [25] pomegranate (Bchir *et al.*, 2012) [14].

Osmotic agent: The type of osmotic agent has a significant impact on the rate of diffusion. Salt, sugar, jaggery, honey, sucrose, glucose, fructose, sorbitol, glycerol, glucose syrup, corn syrup, maple syrup, starch, fructo-oligosaccharides, maltodextrin, and ethanol are all popular osmotic agents (Ahmed *et al.,* 2016 [15]; Brochier *et al.,* 2015) [16]. In general, low molecular weight osmotic agents enter fruit cells more easily than high molecular weight osmotic agents. In osmotic dehydration, an osmotic agent or a mixture of osmotic agents may be used (Table. 1). The osmotic agent must be reliable, practical, non-toxic, and tasty. It should be easily dissolved to form a highly concentrated solution that does not react with the substance, and it should also be inexpensive. Based on efficacy, convenience, and taste, sugar and salt solutions proved to be the best options (Tortoe, 2010) [19]. Sugar solution prevents oxygen entry, stabilises pigments, and aids in the retention of volatile compounds during the drying of osmotically treated products (Pattanapa *et al.,* 2010) [12].

Table 1: Types of osmotic agents and their description

Osmotic Agent	Description	Reference
Calcium chloride	Increase the firmness of apple parts and keep the texture when storing them. Because of the synergistic effect with ascorbic acid or sulphur di oxide, it prevents browning. If used at a concentration of more than 0.5 percent, the product would have a stronger flavor.	Ponting *et al*. (1972)
Ethanol	During the de-hydro cooling process, the viscosity and freezing point of the osmotic solution are reduced.	Biswal and Le Maguer, 1989 [48]
Fructose	Since sucrose has a higher rate of solute penetration than fructose, it is favored. Due to a higher penetration rate, it increases the dry matter content by 50% as compared to sucrose. The final product's water activity is also lower. Sucrose, on the other hand, is favored over fructose.	Bolin *et al.* (1983)
Invert sugar	Since it has twice as many molecules per unit volume when fully inverted, it is more efficient than sucrose at the same concentration. There is only a small variation in the rate of osmotic dehydration.	Ponting *et al*. (1966)
Lactose	It has a much lower sweetness level than sucrose. In aqueous solution, it has a low solubility.	Hawkes and Flink (1978)
Maltodextrin	Can be used at higher total solids concentration or in mixed system.	Khin *et al*. (2007) Hawkes and Flink, 1978
Sodium chloride	Vegetables benefit greatly from this osmotic agent. Browning caused by oxidation and non-enzymatic browning is slowed. Bleaching effects on colored materials can often be avoided by mixing salt and sugar. The concentration should be about 10%. Shrinkage is slowed.	Jackson and Mohamed (1971) [56] Speck *et al.* (1977) Hawkes and Flink (1978) Flink (1980)
Sucrose/sugar	Due to oxidative browning, dry sugar is not suitable. Difficulty in getting rid of the sugar syrup that has developed. Its sweetness makes it unsuitable for vegetable processing.	Ponting *et al*. (1966) Farkas and Lazar (1969) Ponting (1973) [41] Farkas and Lazer, 1969, Flink, 1975
Starch/ corn syrup	As compared to sucrose, it favours a similar final water content with limited solid benefit.	Flink, 1975
Mixture of invert sugar and salt, sucrose and salt, ethanol and salt	Because of the properties of both solutes, they are more efficient than sucrose alone.	Lenart and Flink (1984)

Concentration of osmotic solution: The effect of osmotic solution concentration on mass transfer in the osmotic dehydration phase has been investigated by many researchers. The concentration of osmotic agent, which can affect mass transfer kinetics, is an important variable to investigate. Syrup intensity of 60 to 70° B has been found to be optimal in most cases (Chaudhary *et al.*, 1993) [61]. It was also discovered that the higher the concentration, the faster the osmosis rate. Since the osmotic rate decreases with time, Torreggiani (1993) [11] indicated that using a higher concentration for the osmosis method for more than 50% weight loss was typically not worthwhile. The mass transfer rate of apricot during osmotic dehydration was studied by Ispir and Togrul (2009) [4]. Three separate sucrose concentrations were used to immerse apricot fruits (40%, 50% and 60%). The higher the sucrose concentration, the greater the osmotic pressure gradients, and thus the higher the solid gain and water loss during the osmotic treatment Lazarides *et al.*, (1995) [36] investigated the impact of sucrose concentrations (45, 55, and 65%) on mass transfer during apple osmotic dehydration. Increasing the sucrose concentration resulted in more water loss and solid gain during the osmotic cycle, according to the findings.

Agitation of Osmotic Solution: The use of highly concentrated viscous sugar solutions causes significant issues such as floating food fragments, which obstructs the interaction between food content and the osmotic solution, resulting in a decrease in mass transfer rates. During osmotic dehydration, agitation or stirring may be used to improve mass transfer (Moreira *et al.*, 2007). When the syrup is agitated or distributed around the sample, the OD rises. This is due to a decrease in surface mass transfer resistance. Higher water loss (due to agitation) altering the solute concentration gradient within the food particle may be an indirect result of agitation-induced decreases in solids gain for longer osmosis times. The lower rate of solids gain for longer osmosis cycles caused by agitation may be an indirect result of higher water loss (due to agitation) changing the solute concentration gradient within the good particle (Tortoe, 2010) [19]. Tiwari (2005) [22] discovered that the rate of agitation during osmotic treatment had a positive impact on water loss. Moreira *et al.*, (2007) looked at how stirring affected the osmotic dehydration of chestnut in glycerol solution. The static and dynamic conditions (0 rpm, 40 rpm, and 110 rpm) were evaluated to determine mass transfer.

Temperature during Osmotic solution: Temperature has a major impact on the rate of osmosis. This is the most critical kinetics parameter to consider. Despite the fact that the rate increased with temperature, it was limited to 60 0C because higher temperatures killed cell membranes (Chavan, U.D. and Amarowicz, 2012) [35]. The rate of water loss increases as the temperature rises, while the rate of solid gain is less affected. The mass exchange and diffusion coefficient increase as the rate of osmosis increases, but at temperatures above 50°C, enzymatic browning and flavor degradation occur (Videv *et al.*, 1990). Pokharkar and Prasad (1998) [44] created a kinetic model for osmotic dehydration of banana slices and found that the temperature of the osmotic solution influenced osmosis process parameters such as water and sugar gain. At temperatures above 50^{O}C, it was recorded that undesirable changes occurred on blue berries (Khan, 2012) [23].

Pretreatment methods: The product's intrinsic integrity is affected by pre-treatment conditions prior to the osmotic dehydration process, which has an effect on the mass transfer process (Bekele, Y and Ramaswamy, H., 2010). The rate of osmotic dehydration is primarily determined by the permeability of the cell membrane (Toupin and Le Maguer, 1989) [48]. Osmotic dehydration can occur more quickly if the membrane permeability is high. Many researchers have used pretreatments such as blanching, sulfiting, alkaline dipping, high hydrostatic pressure, and freezing prior to osmotic dehydration to reduce the harmful changes in biological materials induced by traditional drying techniques (Ahmed *et al.*, 2016) [15]. Food products that were soaked in acid or alkaline solutions before drying held their colour. Fruits and vegetables were dipped in 1.0% citric acid solution before osmotic dehydration to avoid enzyme browning (Sunjka & Raghavan, 2004) [42]. Fruit and vegetable discoloration can be avoided by using sulphur dioxide or blanching as a pretreatment. Prior to osmotic dehydration, papaya and mango slices were immersed for 30 minutes in 0.4% ascorbic acid solution and 0.4 percent ascorbic acid + 0.1 percent KMS solution (Torreggiani, 1993) [11]. Del Valle *et al*., (1998) [1] investigated the impact of apple blanching on mass transfer during osmotic dehydration. By steaming apple cylinders, the blanching process was examined (97.3 ºC at 94.6kPa). Blanched samples lost more water than raw samples, according to the findings. These findings were due to material losses as a result of significant cellular tissue damage caused by high temperature blanching. The effect of ohmic heating as a pretreatment before osmotic dehydration on mass transfer of strawberry and apple was investigated by Allali *et al.*, (2010) [2]. A mixture of fruit cubes and syrup with a solid to liquid ratio of 1/2 was treated with ohmic heating. From room temperature (20 °C) to 85 °C, the syrup and fruits were heated.

Immersion time: While the concentration of the solution remained unchanged, increasing the immersion time resulted in an increase in water loss, but at a slower rate. Studies on the impact of time on the osmotic process revealed that mass exchange occurred at a faster pace within the first 2 hours, accompanied by a decrease in drying rate as processing time progressed (Ramaswamy, 2005) [53]. The maximum rate of mass exchange occurred within the first two hours of the osmotic treatment, according to studies on optimizing the length of the osmosis operation. According to Tiwari and Jalali (2004) [54], increased osmotic length resulted in increased weight loss during osmotic dehydration of mango and pineapple, but the rate of weight loss decreased. At a concentration of 45% to 60% and the temperature range of 20 to 50 °C, Mavroudis and Lazarides (1995) [64] discovered that apple slices lost about 25% of their water within the first hour and 40% after the third hour of osmotic therapy.

Ratio of fruit parts to osmotic solution: The rate of osmosis increases to some degree as the solution to sample ratio increases. However, it is important to use an optimal ratio because large ratios make handling the syrup fruit mixture for processing difficult. For practical purposes, a 1:2 or 1:3 ratio is ideal. The majority of researchers used sample-to-solution ratios ranging from 1:1 to 1:5 to investigate mass transfer kinetics by monitoring changes in solution concentration and other variables. In osmotic dehydration, raising the osmotic solution to sample mass ratio resulted in an increase in both solid gain and water loss (Akbarian, M *et al.*, 2014) [66]. Most staff used a high solution to product ratio (at least 30:1) to prevent substantial dilution of the medium and subsequent decrease of the (osmotic) driving force during the process, while some investigators used a much lower solution to product ratio (4:1 or 3:1) to track mass transfer by following changes in the concentration of the sugar solution (Shete, Y.Y. *et al.*, 2018) [32].

The products produced by osmotic dehydration have numerous advantages. Various scholars have written on some of them in various ways. (Chavan, U.D. and Amarowicz, 2012 [35]; Shete, Y.Y *et al.*, 2018 [32]; Ponting *et al.*, 1966 and Islam and Flink, 1982) [47] are reported.

Advantages of OD

Water activity is not sufficiently reduced by osmotic dehydration to prevent microorganism proliferation. The method prolongs the material's shelf life, but it does not preserve it. It's ready to eat and doesn't need rehydration. Food's chemical composition may be adjusted to meet specific requirements. Person requirements can be met by adjusting the amount of osmoactive material that penetrates the tissue. The raw material's mass is reduced, typically by half. Since no high temperature/phase shift is needed in the process, it reduces the impact of temperature on food quality and preserves the wholeness of the food. The product's superior organoleptic characteristics are due to the product's moderate heat treatment, which promotes colour and flavour preservation. When sugar syrup is used as an osmotic agent, the difference is even greater. The process is straightforward, cost-effective, and energy-efficient as compared to traditional drying methods. It inhibits polyphenol oxidase and prevents enzymatic browning. Because the product is constantly immersed in osmotic agents, it is not exposed to oxygen and retains its colour better. It prevents the product's structure from collapsing during the drying process. It aids the dehydration of products in maintaining their shape. Osmo dehydration does not necessitate the use of expensive or complicated equipment. The osmotic solution that is left over can be used in the beverage industry to improve process economy, or it can be re-used for drying.

The removal of acid and uptake of sugar by the fruit parts results in a sweeter product than a dried product. Higher moisture content is permitted at the end of drying if salt is used as an osmotic agent since salt absorption affects water sorption conduct. After reconstitution, the textural consistency of the product improves.

Rather than advantages, there are some of the limitations of osmotic dehydration which are reported by Ponting *et al.*, 1966 and Jackson & Mohammad, 1971 [56].

Limitations of OD

The acidity level of certain products is reduced, which decreases their distinctive flavour. Fruit acid may be added to the solution to counteract this. In some goods, sugar coating is undesirable, and a fast rinse in water after treatment may be needed. Osmotic dehydration was found to be expensive when combined with other processes like vacuum drying, air drying, or blanching. The water activity is higher in osmotic dehydrated products. It's a lengthy procedure.

Effect of osmotic dehydration in fruit and vegetable crops

Because of its advantages, a novel technique for partial dehydration of fruits is being attempted. It entails immersing food in concentrated sugar or salt solutions for an extended period of time until water loss and solute impregnation occur. Osmo-canning of apple rings was defined by Sharma *et al.*, (1991) [50]. The rings were soaked in a 70% sugar solution for half an hour at 50°C before being canned in 35°B syrup. The use of this new technology resulted in a firm texture, improved consistency, and the drained weight that was desired. Moisture infusion technique was used to osmotically dehydrate papaya slices of 15 mm thickness in a soak solution comprising 60% sucrose, 0.1 percent citric acid, and 0.1 percent potassium sorbate for an overnight period (Ahmed and Choudhary, 1995) [46]. During that time, the slices reached a temperature of 44°B. Sankat *et al.*, (1996) [51] soaked a 10 mm thick Cavendish banana in sugar solutions of 35, 50, and 65°B for 36 hours. When dipped in the three solutions, the moisture content of the fruit decreased from 3.13 to 2.19, 1.63 and 1.16 kg H20 kg'1 DM, and TSS reached 26, 34, and 39°B, respectively. The mass transition during osmotic dehydration of high pressure treated (200 MPa) and untreated strawberry halves was studied by Taiwo *et al.*, (2003). Falade, Igbeka, and Ayanwuyi (2007) [49, 52] used three separate concentrations of sucrose solution (40°B, 50°B and 60°B) to investigate the osmotic mass transfer phenomenon of water melon slabs. Water loss and solid gain were found to be higher in the watermelon slabs treated with the higher osmotic solution concentration. When comparing high pressure treated strawberry halves to untreated samples, higher water loss and solid gain were found. Changrue *et al.*, (2008) [65] investigated the effect of osmotic dehydration on the dielectric properties of carrot and strawberries. Sucrose and salt were used as osmotic agents on carrots, but only sucrose was used on strawberries. Bchir *et al.*, (2011) investigated the impact of prefreezing pomegranate seeds prior to osmotic dehydration. Prior to osmotic dehydration, freezing caused 1.4 and 3.5 times more water loss and solid gain, respectively, than an untreated sample at the start of the method. High pressure pretreatment of banana slices increased the mass transfer rate during osmotic dehydration, according to Verma, Kaushik, and Rao (2014) [24].

Conclusion

Water makes up 75-95% of fresh fruits and vegetables, and using the OD is one way to reduce the water content at first. O.D. is a technique for removing moisture from food products in a partial manner. Due to the greater sensory resemblance between the dehydrated and natural product, it has been regarded as a method of acquiring minimally processed fruits and vegetables. The driving force of the process is the difference in osmotic pressure between the immersion solution and the product. Up to 50% of the water in the original fruit or vegetable may be removed during the O.D process. Water will be lost, and the substance will most likely gain solutes from the immersion solution. It also has other advantages, such as mitigating thermal damage to nutrients, preventing enzymatic browning, and lowering costs. Variables such as the food material's range, maturity level, and geometry, as well as pretreatments, temperature, concentration, and forms of osmotic agent, all influence mass transfer during O.D. The integrity of natural tissue is influenced by pretreatment methods. Osmotic soaking reduces product exposure to oxidation degradation and partial dehydration, as well as solute absorption by the product, which prevents structural collapse during the drying phase. As a result, osmotically dehydrated products have improved flavour, texture, and taste than untreated products. Since the osmotic dehydration process is easy, it allows for the processing of tropical fruits and vegetables such as bananas, sapotas, pineapples, mangos, guavas, carrots, pumpkins, papayas, etc. while retaining their original colour, aroma, and nutritional content. The osmotic dehydration process adds value to the final product, which is safe, nutritious, and accessible all year. This method could be used on a small scale to help self-employed people and home-based businesses develop. Consumption of such nutritious and valuable products could be promoted through exhibition and media. However, since no preservatives were used, this procedure is very cost effective and has no negative effects on the human body. It has the potential to reduce fruit and vegetable post-harvest losses.

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